III. *Account of Magnetic Observations made in the years* 1858–61 *inclusive, in British Columbia, Washington Territory, and Vancouver Island. By Captain* R. W. Haig, *R.A. Communicated by General* Sabine, *P.R.S.*

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In 1858 a Commission was appointed for the purpose of determining and marking the forty-ninth parallel of north latitude from the Pacific to the Rocky Mountains. At the suggestion of General Sabine, this Commission was provided with a set of portable magnetic instruments adapted for the determination of the three magnetic elements, Dip, Declination, and Total Force. These instruments were similar in kind to those which had been used on the Magnetic Survey of the United Kingdom. Before delivery to the Boundary Commission they were examined at the Kew Observatory, and several constants and tables for facilitating the computations were determined and prepared there.

The method of transporting the instruments from place to place, and indeed everything appertaining to the Boundary Commission, was by means of packet mules. Two boxes (a very light load for one mule) contained all the magnetic instruments, which throughout four years of such rough usage retained their original efficiency. Some of the needles became somewhat rusted; but I can suggest no alteration in the construction of such instruments, such as would increase their portability. The declinometer was, I think, unsatisfactory as regarded its capability of determining azimuths of the sun: when at an astronomical station, I necessarily had a meridian mark for the transit instrument, and I referred the direction of the magnet to such meridian.

In assembling the results and deducing from them the directions and positions of the lines of equal dip, force, and declination, no notice has been taken of secular change. The only station at which we have data for judging of the extent of secular change is Fort Vancouver on the Columbia River. As regards dip, we find there

1830.	Dip 69° 39′·7	Douglas.
1839.	Dip 69 22·2	Sir E. Belcher.
1860.	Dip 69 17·4	Present observations.

These figures show an annual diminution of dip of less than 1′ per annum. The mean results of the present observations may be assumed to belong to the year 1860. The method of assembling the results and determining from them the position and direction of the lines of equal dip, force, and declination, is the same as that adopted in the Survey of the United Kingdom.

It consists in referring all the results to the point of mean longitude and latitude among all the stations, and assuming the differences of longitude and latitude expressed in geographical miles to be plane rectangular coordinates of distance from the origin. It is also assumed that the three magnetic elements vary uniformly over the whole district surveyed.

Dip.

Table I. gives the individual results at each station, as well as the partial results from the needle when magnetized in opposite directions. Table II. shows the mean results, along with the most probable dip at each station computed by the method of minimum squares. By the method of minimum squares the variation of dip for one mile of longitude $x = +0'{\cdot}272$, and the variation for one mile of latitude $y = +0'{\cdot}776$; from these values we get $u = 70°\ 42'$ for the angle which an isoclinal line makes with the meridian measured from the north round by west, and $\frac{1}{r}$ or $\frac{1}{\sqrt{x^2+y^2}} = 1{\cdot}216$ mile for the distance between isoclinals whose difference of dip is 1′. Column 5 contains the most probable dip at each station (θ'), obtained from equations $\theta' = \theta_1 + ax + by$. The probable error of the computed dip at each station is nearly equal to $\pm 5'$.

Intensity of the Magnetic Force.

The stations where these observations were made are the same as the dip stations. At ten of them observations of deflection and vibration for the horizontal component were made with the unifilar, and observations by Lloyd's statical method for variation of the total force; at the remaining eleven stations the statical method only was employed.

Observations at the first ten stations furnish values of the constant log A, of which a mean value might be adopted for use at the other eleven; but from an examination of these values of log A, it appears that those belonging to 1861 are generally larger than preceding values, owing, I believe, to the weighted needle having become rusted. I have therefore adopted the mean of all values of log A previous to 1861 for statical observations up to that period, and the mean of those in 1861 for observations in that year. The first value is log A = 0·91931, and that for 1861 is log A = 0·92032.

Table III. shows the unifilar observations, and the values of X, the horizontal component of the magnetic intensity, derived from them. Column 12 of this Table contains the dips at the several stations, and column 13 the total force $\varphi = X \sec \theta$.

Panama, the first station in this Table, is not included in the general assemblage of results in Table IV., its distance from the other stations being too great. Table IV. shows the combination of all observations for force to determine the direction and distance apart of the isodynamic lines. Column 3 in this Table corresponds to column 13 in Table III. We find (x) the variation in total force for one mile of longitude $= +0{\cdot}000925$, and (y) the variation for one mile of latitude $= +0{\cdot}000896$; $\frac{1}{r}$ the distance between the isodynamic lines a unit of force apart = 776·6 miles, or for a tenth

part of a unit = 77·66 miles; u, the angle which isodynamic lines make with the meridian measured from the north round by west, is 44° 6′. Column 11 of Table IV. contains the most probable value of the total force at each station, and the probable error of one such value is ±0·044.

Declination.

Table V. is similar in character to Tables II. and IV.; by it we find (x) the increase of declination for one mile of longitude = +0′·230, and (y) the increase of declination for one mile of latitude = +0′·423; $\frac{1}{r}$ the distance between lines of equal variation 1′ apart = 2·0756 miles; therefore, for 1° of difference in the declination, the distance is 124·54 miles; u, the angle which lines of equal declination make with the meridian measured from the north round by west, is 61° 27′. The most probable declinations are shown in column 5 of Table V., and the probable error of one such result is ±27′.

The results contained in Tables II., IV. and V. are represented graphicaly in Plate III., which exhibits a map of the country surveyed, with the lines of equal inclination, declination, and intensity drawn upon it.

TABLE I.—Dip.

1. Date.	2. Needle.	3. Station.	4. Poles direct.	5. Poles reversed.	6. Dip.	7. Mean dip.
			° ′	° ′	° ′	° ′
1858. August 19 ...	1	Esquimalt	71 18·94	71 42·06	71 30·5	
1859. March 18 ...	4	„	71 31·55	71 42·78	71 37·2	71 34·2
1860. March 22 ...	1	„	71 23·00	71 46·20	71 34·9	
1858. Oct. 4 ...	1	Sumass Prairie	72 12·08	72 29·15	72 20·6	
5 ...	4	„	72 16·66	72 29·88	72 23·3	72 22·0
1859. Jan. 31 ...	4	Nisqually	70 29·62	70 49·56	70 40·0	
July 4 ...	1	Schweltza Lake	71 57·31	72 13·68	72 05·8	
5 ...	1	„	71 50·44	72 13·25	72 01·9	72 03·9
Sept. 7 ...	1	Chilukweyuk Lake	72 19·60	72 42·40	72 31·0	
1860. May 3 ...	1	Fort Vancouver, W. T.	69 02·83	69 31·88	69 17·4	
21 ...	1	Dalles, W. T., 3-mile camp.....	69 29·90	69 53·80	69 41·8	
June 1 ...	1	„ 8-mile camp.....	69 55·12	70 13·66	70 04·5	
July 9 ...	4	On Ashtnolou River	72 29·09	72 44·79	72 36·9	
August 18 ...	1	Ashtnolou Station	72 16·80	72 37·20	72 27·0	
Nov. 13 ...	4	Inshwointum	72 34·75	73 02·90	72 48·8	
1861. March 26 ...	4	Fort Colville.....	72 51·81	73 33·93	72 42·9	
April 2 ...	4	„	72 44·60	72 56·50	72 50·6	72 41·9
12 ...	4	„	72 32·40	72 44·70	72 38·5	
23 ...	4	„	72 34·20	72 36·70	72 35·5	
May 19 ...	1	Chemikane River.....	71 45·40	72 24·60	72 04·2	
31 ...	4	Sinyakwateen	72 29·60	72 42·00	72 35·8	
31 ...	1	„	72 17·31	72 50·61	72 34·0	72 34·9
June 19 ...	1	Pack River	72 31·62	72 59·44	72 45·5	
23 ...	1	Chelemta	72 54·56	73 21·50	73 08·0	
July 6 ...	1	South Crossing (Kootenay).....	72 37·50	72 59·00	72 48·1	
12 ...	1	On Kootenay River.....	72 57·31	73 17·06	73 07·2	
August 19 ...	1	Tobacco Plains (Kootenay).....	73 16·06	73 29·44	73 22·9	
14 ...	1	Wigwam River Station	73 27·06	73 34·62	73 31·0	
2 ...	1	Akamina Station	73 34·12	73 51·31	73 42·7	

TABLE II.—Dip.

1.	2.	3.	4.	5.
Station.	W. Longitude. μ.	N. Latitude. λ.	Observed dip. θ.	Computed dip. θ'.
	° ′	° ′	° ′	° ′
Esquimalt	123 27	48 26	71 34	71 30
Sumass Prairie	122 12	49 01	72 22	72 11
Nisqually	122 25	47 07	70 40	70 39
Schweltza Lake Station	122 00	49 02	72 04	72 14
Chilukweyuk Lake	121 23	49 02	72 31	72 21
Fort Vancouver	122 28	45 38	69 17	69 28
Dalles, 3-mile camp	120 49	45 35	69 42	69 45
Dalles, 8-mile camp	120 49	45 40	70 05	69 49
On Ashtnolou River	120 00	49 10	72 37	72 42
Ashtnolou Station	120 00	49 00	72 27	72 34
Inshwointum Station	118 28	49 00	72 49	72 50
Colville B. B. C. Barracks Station	118 05	48 40	72 42	72 39
Chemikane River	117 45	48 00	72 04	72 12
Sinyakwateen	116 44	48 09	72 35	72 30
Pack River	116 28	48 22	72 46	72 43
Chelemta	116 19	48 41	73 08	72 59
South Crossing (Kootenay)	115 21	48 22	72 48	72 55
On Kootenay River	115 17	48 40	73 07	73 09
Tobacco Plains (Kootenay)	115 08	48 57	73 23	73 24
Wigwam River Station	114 45	49 00	73 31	73 30
Akamina Station	114 04	49 01	73 43	73 38
	393 57	172 33	45 55	
μ_1, λ_1, and θ_1 respectively	118 45	48 13	72 11	
Probable error of a single observation $= \pm 4{\cdot}93$*.				

* This of course includes the effects of local irregularities in terrestrial magnetism as well as actual errors of observation. A similar remark applies to Tables IV. and V.

TABLE III.—Intensity of the Magnetic Force.

Observations with the Unifilar Magnetometer. Vibrations and Deflections.

1. Date.	2. Station.	3. N. Latitude.	4. W. Longitude.	5. r_0.	6. u_0.	7. $\log \frac{m}{x}$.	8. $\log T^2$.	9. $\log \pi^2 K$.	10. $\log mX$.	11. X.	12. δ.	13. φ.
				feet.								
1858. April 29	Panama	8° 5′	79° 31′	1	9° 10′ 41″·0	8·90771	.....	.....	.....	.....	32° 30′	
30	.....	.....	.....	1	9 8 29·0	8·90594	1·60697	1·66866	0·66353	7·6283	.....	9·0447
30	.....	.....	.....	...	.....	.....	1·59077	1·66861	0·67986			
May 1	.....	.....	.....	1	9 8 49·0	8·90636	1·59065	1·66859	0·68000	7·7058	.....	9·1367
2	.....	.....	.....	1	9 6 49·0	8·90479	1·59117	1·66858	0·67949	7·6270	.....	9·0433
3	Taboga Island	8 48	79 32	1	9 10 53·0	8·90730	1·59272	1·66858	0·67794	7·6793	32 12	9·0753
Oct. 13	Sumass Prairie	49 01	122 12	1	11 46 53·5	9·01242	.....	.....	.....	.....	72 22	
21	.....	.....	.....	1	11 49 02·1	9·01324						
21	.....	.....	.....	1·3	5 21 33·6	9·01348						
Nov. 1	.....	.....	.....	...	.....	.....	1·44048	1·66836	0·22788			
10	.....	.....	.....	...	.....	.....	1·43994	1·66837	0·22843	4·0509	.....	13·3727
1859. Jan. 24	Esquimalt, V. I.	48 26	123 27	1	11 42 19·6	9·00831	1·43593	1·66835	0·23242	4·0935	71 34·1	12·9474
24	.....	.....	.....	1·3	5 18 11·5	9·00812						
March 21	.....	.....	.....	1	11 33 05·4	9·00374						
21	.....	.....	.....	1·3	5 14 17·7	9·00375						
22	.....	.....	.....	...	.....	.....	1·42962	1·66835	0·23876	4·1449	.....	13·1097
1860. May 3	Fort Vancouver, W. T.	45 38	122 28	1	10 20 29·2	8·95700	.....	.....	.....	4·6180	69 17·4	13·0585
8	.....	.....	.....	...	.....	.....	1·38249	1·66839	0·28590			
Aug. 17	Ashtnolou Station	49 00	120 00	1	11 52 20·4	9·01711	1·44514	1·66865	0·22351	4·0105	72 37·0	13·3003
1861. April 18	Fort Colville	48 40	118 05	1	11 49 30·3	9·01583	.....	.....	.....	.....	72 41·9	13·4239
23	.....	.....	.....	1	11 54 39·6	9·01679	1·44954	1·66834	0·21880			
23	.....	.....	.....	...	.....	.....	1·44964	1·66835	0·21871	3·9923		
May 31	Sinyakwateen	48 09	116 44	1	11 48 59·7	9·01459	1·44705	1·66847	0·22142	4·0125	72 34·9	13·4045
June 19	Pack River	48 22	116 28	1	11 57 17·0	9·01957	1·45167	1·66845	0·21678	3·9683	72 45·5	13·3881
23	Chelemta River	48 41	116 19	1	12 09 22·0	9·02602	1·45766	1·66839	0·21073	3·9116	73 08·0	13·4816
July 6	South Crossing (Kootenay)	48 22	115 21	1	11 55 50·0	9·01860	1·45159	1·66845	0·21686	3·9731	72 48·2	13·4384
15	Wigwam River	49 00	114 45	1	12 21 41·0	9·03485	1·46796	1·66849	0·20053	3·8268	73 30·8	13·4850

TABLE IV.—Total Force.

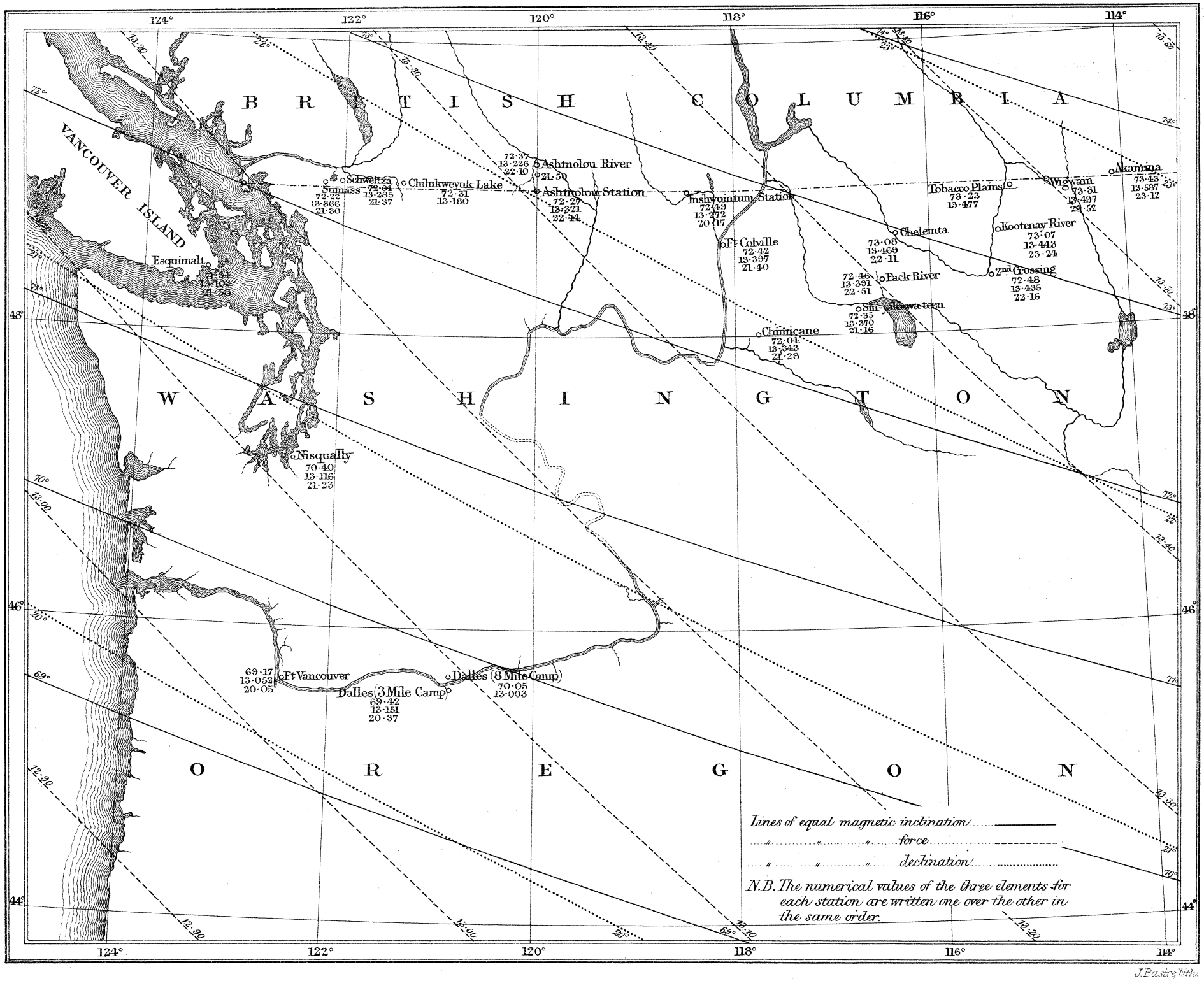
1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
Year.	Station.	φ by unifilar.	log φ.	log $\sqrt{\frac{\cos n}{\sin u \sin u'}}$.	log A.	Mean log A.	log φ.	Statical φ.	Adopted φ.	φ'.
1859–60	Esquimalt	13·1097	1·11759	0·19781	0·91978	0·91931	1·11712	13·0955	13·103	13·148
1858	Sumass Prairie	13·3727	1·12622	0·20647	0·91975	0·91931	1·12578	13·3591	13·366	13·226
1859	Nisqually	.....	.....	0·19848	.....	0·91931	1·11779	13·1158	13·116	13·111
do.	Schweltza Lake Station	.....	.....	0·20406	.....	0·91931	1·12337	13·2853	13·285	13·234
do.	Chilukweyuk Lake	.....	.....	0·20062	.....	0·91931	1·11993	13·1803	13·180	13·257
1860	Fort Vancouver	13·0585	1·11589	0·19614	0·91975	0·91931	1·11545	13·0451	13·052	13·026
do.	Dalles, 3-mile camp	.....	.....	0·19964	.....	0·91931	1·11895	13·1506	13·151	13·087
do.	Dalles, 8-mile camp	.....	.....	0·19472	.....	0·91931	1·11403	13·0026	13·003	13·091
do.	On Ashtnolou River	.....	.....	0·20210	.....	0·91931	1·12141	13·2255	13·226	13·315
do.	Ashtnolou Station	13·3003	1·12386	0·20589	0·91797	0·91931	1·12520	13·3412	13·321	13·306
do.	Inshwointum Station	.....	.....	0·20364	.....	0·91931	1·12295	13·2724	13·272	13·361
1861	Colville B. B. C. Barracks	13·4239	1·12788	0·20584	0·92204	0·92032	1·12616	13·3709	13·397	13·357
do.	Chemikane River	.....	.....	0·20493	.....	0·92032	1·12525	13·3428	13·343	13·334
do.	Sinyakwateen	13·4045	1·12725	0·20471	0·92254	0·92032	1·12503	13·3361	13·370	13·238
do.	Pack River	13·3881	1·12672	0·20660	0·92012	0·92032	1·12692	13·3944	13·391	13·401
do.	Chelemta	13·4816	1·12974	0·20863	0·92111	0·92032	1·12895	13·4570	13·469	13·423
do.	South Crossing (Kootenay)	13·4384	1·12835	0·20779	0·92056	0·92032	1·12811	13·4309	13·435	13·443
do.	On Kootenay River	.....	.....	0·20816	.....	0·92032	1·12848	13·4425	13·443	13·460
do.	Tobacco Plains (Kootenay)	.....	.....	0·20927	.....	0·92032	1·12959	13·4769	13·477	13·481
do.	Wigwam River Station	13·4850	1·12985	0·21029	0·91956	0·92032	1·13061	13·5085	13·497	13·496
do.	Akamina Station	.....	.....	0·21281	.....	0·92032	1·13313	13·5872	13·587	13·522

$$\varphi_1 = 13{\cdot}309 \quad \frac{6484}{}$$

Probable error of a single observation $= \pm 0{\cdot}044$

TABLE V.—Declination.

1.	2.	3.	4.	5.
Station.	W. Longitude. μ.	N. Latitude. λ.	Declination. v.	v'.
Esquimalt	123° 27′	48° 26′	21° 58′	21° 20′
Sumass Prairie	122 12	49 01	21 30	21 42
Nisqually	122 25	47 07	21 23	20 51
Schweltza Lake	122 00	49 02	21 37	21 44
Fort Vancouver	122 28	45 38	20 05	20 13
Dalles, 3-mile camp	120 49	45 35	20 37	20 27
On Ashtnolou River	120 00	49 10	22 10	22 06
On Ashtnolou River	120 00	49 07	21 50	22 04
Ashtnolou Station	120 00	49 00	22 44	22 12
Osoyoos Station	119 24	49 00	22 14	22 07
Inshwointum	118 28	49 00	20 17	22 15
Colville B. B. C. Barracks	118 05	48 40	21 40	22 11
Chemikane River	117 45	48 00	21 28	21 57
Sinyakwateen	116 44	48 09	21 16	22 10
Pack River	116 28	48 22	22 51	22 19
Chelemta	116 19	48 41	22 11	22 27
South Crossing (Kootenay)	115 21	48 22	22 16	22 28
On Kootenay River	115 17	48 40	23 24	22 36
Wigwam Station	114 45	49 00	23 52	22 50
Akamina Station	114 04	49 01	23 12	22 56
	376 01	167 01	38 35	
	118 48	48 21	21 56	
Dalles, 8-mile camp	120 49	45 40	18 44	Rejected.
Probable error of a single result $= \pm 27{\cdot}06$.				


124°
122°
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44°
BRITISH COLUMBIA
VANCOUVER ISLAND
WASHINGTON
OREGON
Esquimalt
71·34
13·102
21·58
Nisqually
70·40
13·116
21·23
Schweltza
Sumass
72·22
13·366
21·30
72·04
13·285
21·37
Chilukweyuk Lake
72·31
13·180
72·37
13·226
22·10
Ashtnolou River
21·50
Ashtnolou Station
72·27
13·321
22·44
Inshwointum Station
72·43
13·272
20·17
Ft Colville
72·42
13·397
21·40
Chelemta
73·08
13·469
22·11
Tobacco Plains
73·23
13·477
Kootenay River
73·07
13·443
23·24
Wigwam
73·31
13·497
23·52
Akamina
73·43
13·587
23·12
Pack River
72·46
13·391
22·51
2nd Crossing
72·48
13·435
22·16
Sin-yak-wa-teen
72·35
13·370
21·16
Chimicane
72·04
13·343
21·28
69·17
13·052
20·05
Ft Vancouver
Dalles (3 Mile Camp)
69·42
13·151
20·37
Dalles (8 Mile Camp)
70·05
13·003
Lines of equal magnetic inclination
" " force
" " declination
N.B. The numerical values of the three elements for each station are written one over the other in the same order.